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(54) **OPTIMIZED REAL-TIME ANTISKID CONTROL INITIALIZATION FOR TRAVEL SURFACES AS A FUNCTION OF WHEEL SPINUP**

(71) Applicant: **THE BOEING COMPANY**, Chicago, IL (US)

(72) Inventor: **Thomas Todd Griffith**, Chicago, IL (US)

(73) Assignee: **THE BOEING COMPANY**, Chicago, IL (US)

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B60T 8/17	(2006.01)
B60T 8/176	(2006.01)

(52) **U.S. Cl.**

CPC ***B64C 25/46*** (2013.01); ***B60T 8/1703*** (2013.01); ***B60T 8/176*** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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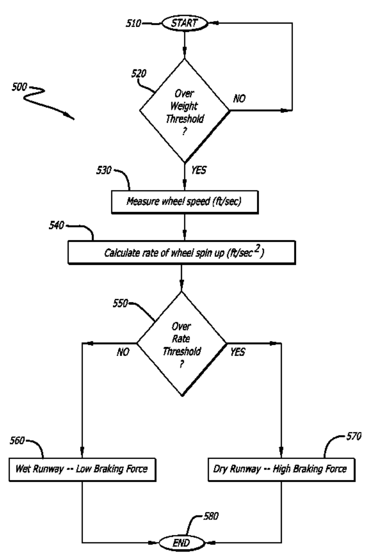
Primary Examiner — Adam Alharbi

(74) *Attorney, Agent, or Firm* — Vista IP Law Group LLP; Cynthia A. Dixon

(57) **ABSTRACT**

Systems, methods, and apparatus for optimizing real-time antiskid control initialization for a vehicle on a travel surface are disclosed. In one or more embodiments, a method involves determining when at least one wheel of the vehicle touches ground. The method further involves calculating a rate of wheel spin up for at least one wheel. Also, the method involves determining whether the rate of wheel spin up exceeds a wheel spin up rate threshold. In addition, the method involves applying a high level of brake force when the rate of wheel spin up exceeds the wheel spin up rate threshold, and applying a low level of brake force when the rate of wheel spin up does not exceed the wheel spin up rate threshold.

11 Claims, 4 Drawing Sheets



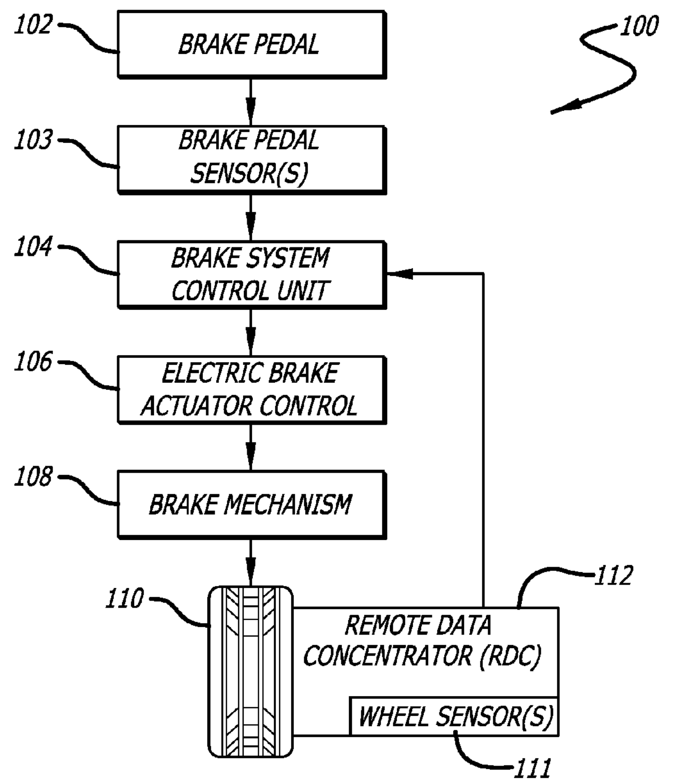

100
102
BRAKE PEDAL
103
BRAKE PEDAL SENSOR(S)
104
BRAKE SYSTEM CONTROL UNIT
106
ELECTRIC BRAKE ACTUATOR CONTROL
108
BRAKE MECHANISM
110
112
REMOTE DATA CONCENTRATOR (RDC)
WHEEL SENSOR(S)
111

FIG. 1

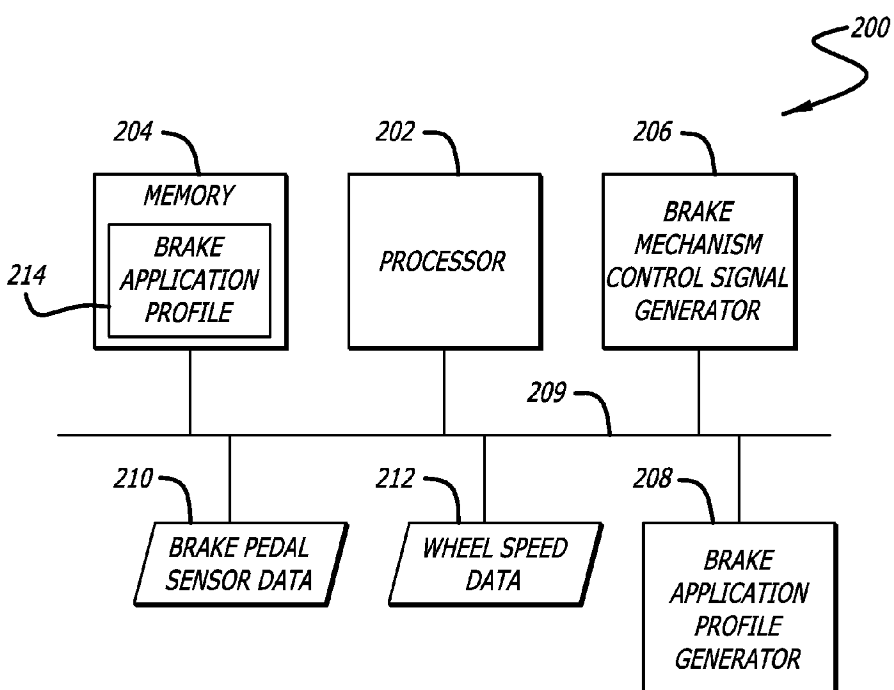

200
204
MEMORY
BRAKE APPLICATION PROFILE
214
202
PROCESSOR
206
BRAKE MECHANISM CONTROL SIGNAL GENERATOR
209
210
BRAKE PEDAL SENSOR DATA
212
WHEEL SPEED DATA
208
BRAKE APPLICATION PROFILE GENERATOR

FIG. 2

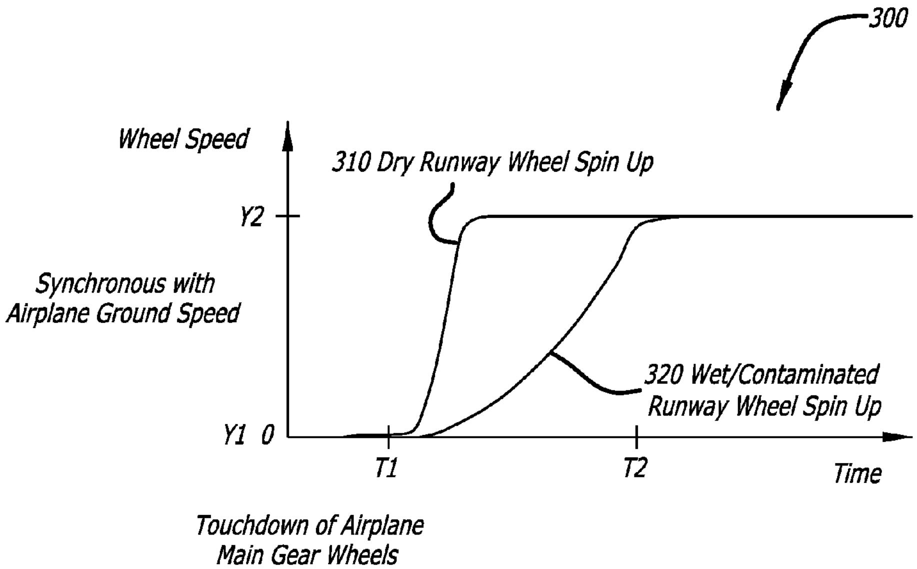

300
Wheel Speed
310 Dry Runway Wheel Spin Up
Y2
Synchronous with
Airplane Ground Speed
320 Wet/Contaminated
Runway Wheel Spin Up
Y1 0
T1
T2
Time
Touchdown of Airplane
Main Gear Wheels

FIG. 3

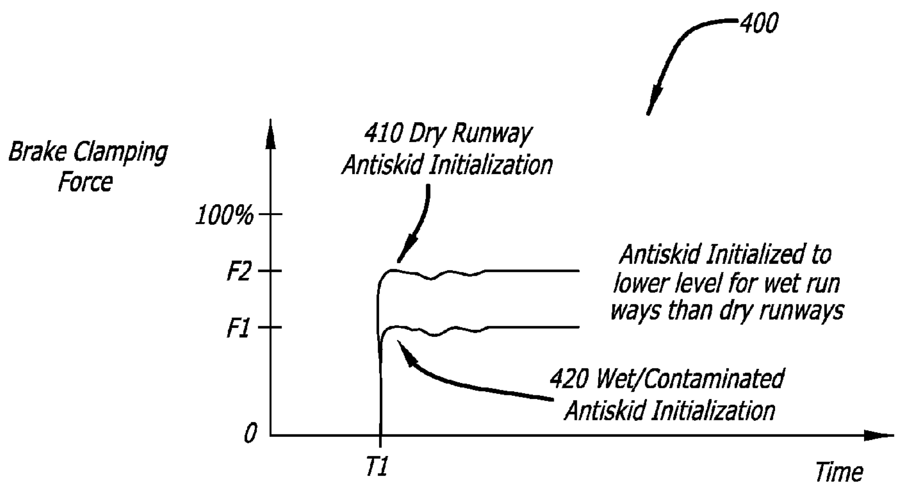
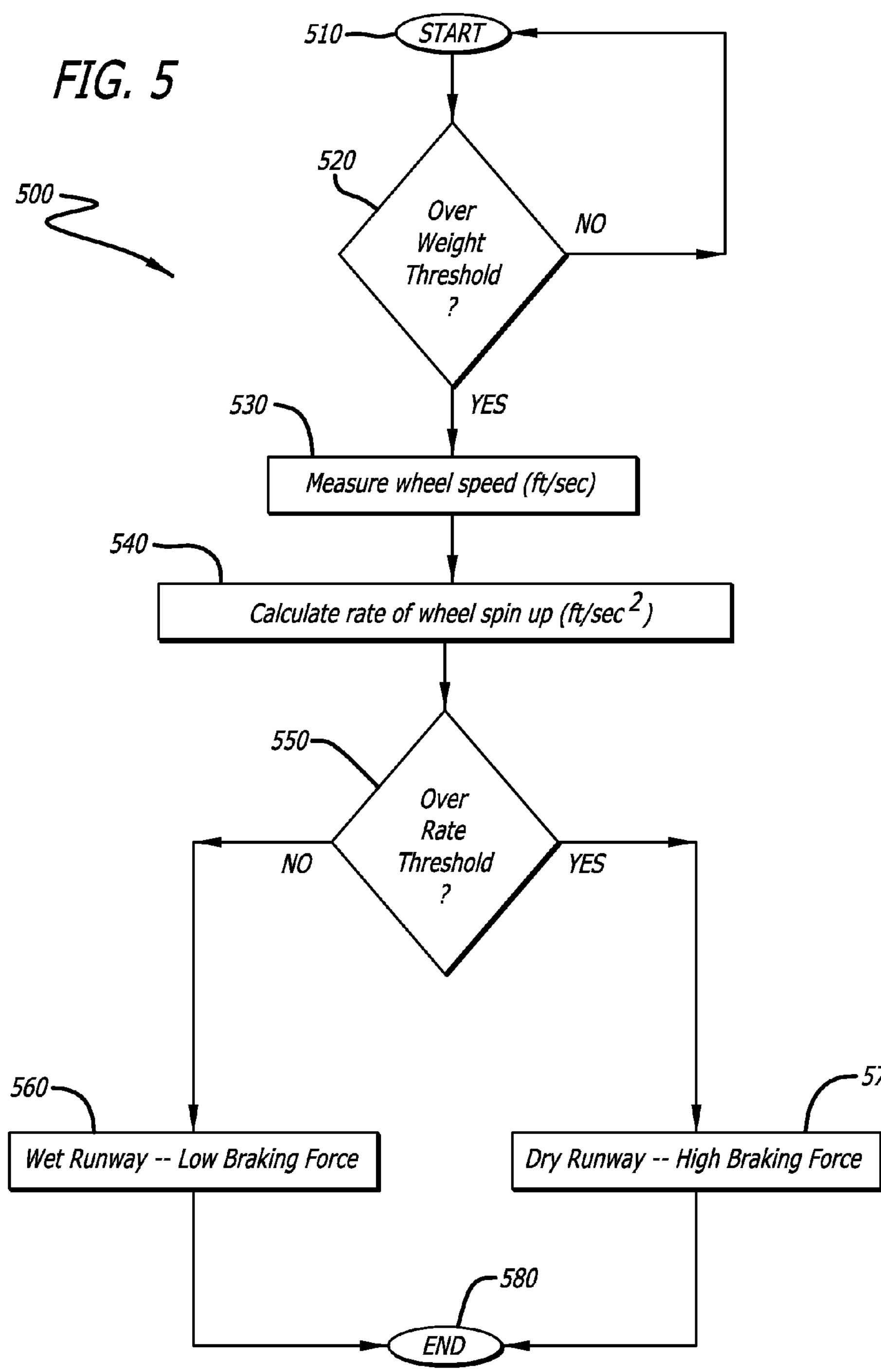

400
Brake Clamping
Force
410 Dry Runway
Antiskid Initialization
100%
F2
F1
Antiskid Initialized to
lower level for wet run
ways than dry runways
420 Wet/Contaminated
Antiskid Initialization
0
T1
Time

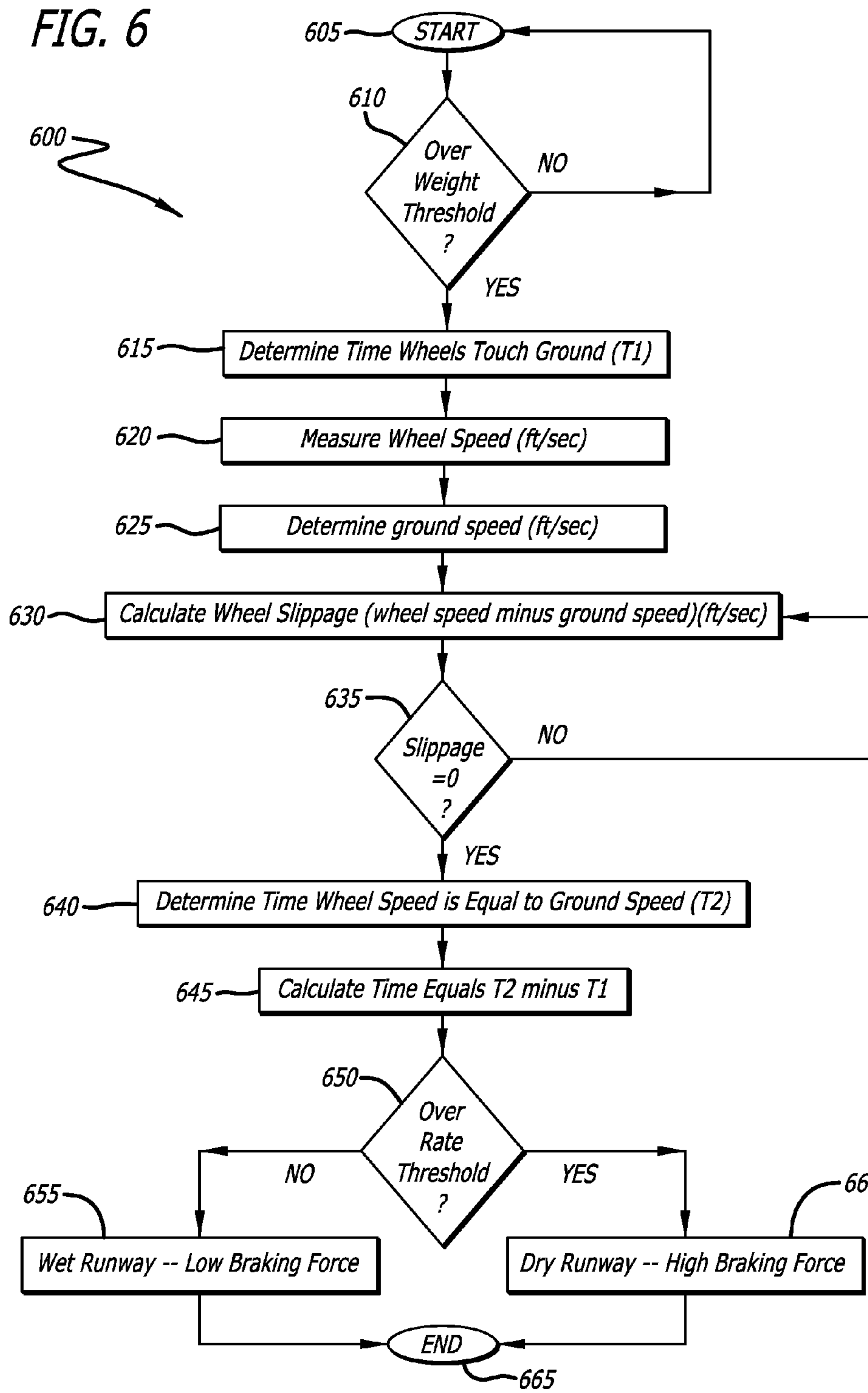
FIG. 4

FIG. 5



500
510
START
520
Over Weight Threshold ?
NO
YES
530
Measure wheel speed (ft/sec)
540
Calculate rate of wheel spin up (ft/sec 2)
550
Over Rate Threshold ?
NO
YES
560
Wet Runway -- Low Braking Force
570
Dry Runway -- High Braking Force
580
END

FIG. 6


600
605
START
610
Over Weight Threshold ?
NO
YES
615
Determine Time Wheels Touch Ground (T1)
620
Measure Wheel Speed (ft/sec)
625
Determine ground speed (ft/sec)
630
Calculate Wheel Slippage (wheel speed minus ground speed)(ft/sec)
635
Slippage =0 ?
NO
YES
640
Determine Time Wheel Speed is Equal to Ground Speed (T2)
645
Calculate Time Equals T2 minus T1
650
Over Rate Threshold ?
NO
YES
655
Wet Runway -- Low Braking Force
660
Dry Runway -- High Braking Force
END
665

OPTIMIZED REAL-TIME ANTISKID CONTROL INITIALIZATION FOR TRAVEL SURFACES AS A FUNCTION OF WHEEL SPINUP

FIELD

The present disclosure relates to optimized antiskid control initialization. In particular, it relates to real-time antiskid control initialization for vehicles on travel surfaces a function of wheel spinup.

BACKGROUND

Currently, existing vehicle antiskid control initialization is optimized for dry travel surfaces due to the lack of input to indicate what the real-time travel surface condition (e.g., the coefficient of friction (μ)) may be under other conditions, such as during rain, snow, ice, or contamination. This leads to a less than optimized wet/contaminated runway performance because the antiskid control will take longer to initialize in other than dry travel surface conditions. The present disclosure allows for the selection of the appropriate antiskid control initialization based on the real-time condition of the travel surface, for example detected during touchdown and de-rotation of the wheels of an aircraft.

SUMMARY

The present disclosure relates to a method, system, and apparatus for optimized antiskid control initialization for travel surfaces as a function of wheel spinup of a vehicle. In one or more embodiments, a method for optimizing real-time antiskid control initialization for a vehicle on a travel surface involves determining, with at least one processor, when at least one wheel of the vehicle touches ground. The method further involves calculating, with at least one processor, a rate of wheel spin up for at least one wheel. Also, the method involves determining, with at least one processor, whether the rate of wheel spin up exceeds a wheel spin up rate threshold. In addition, the method involves applying, with at least one brake for at least one wheel, a high level of brake force, when the rate of wheel spin up exceeds the wheel spin up rate threshold. Further, the method involves applying, with at least one brake for at least one wheel, a low level of brake force, when the rate of wheel spin up does not exceed the wheel spin up rate threshold.

In one or more embodiments, the determining of when at least one wheel of the vehicle touches the ground involves determining, with at least one wheel sensor, a weight on at least one wheel; and determining, with at least one processor, whether the weight on at least one wheel exceeds a weight threshold. In at least one embodiment, the weight threshold is related to a size of the vehicle.

In at least one embodiment, the method further involves measuring, with at least one wheel sensor, a speed of at least one wheel. In some embodiments, the calculating of the rate of wheel spin up involves at least one processor using the speed of at least one wheel.

In one or more embodiments, the wheel spin up rate threshold is around 1000 feet per second squared (ft/sec^2). In at least one embodiment, the high level of brake force is about 1500 to 3000 pounds per square inch (psi). In some embodiments, the low level of brake force is about 300 to 1500 psi. In one or more embodiments, the vehicle is an aircraft or a space plane. In some embodiments, at least one brake is a forward brake and/or an aft brake.

In at least one embodiment, a system for optimizing real-time antiskid control initialization for a vehicle on a travel surface involves at least one processor to determine when at least one wheel of the vehicle touches ground, to calculate a rate of wheel spin up for at least one wheel, and to determine whether the rate of wheel spin up exceeds a wheel spin up rate threshold. The system further involves at least one brake, for at least one wheel, to apply a high level of brake force when the rate of wheel spin up exceeds the wheel spin up rate threshold, and to apply a low level of brake force when the rate of wheel spin up does not exceed the wheel spin up rate threshold.

In one or more embodiments, to determine when at least one wheel of the vehicle touches the ground involves at least one wheel sensor to determine a weight on at least one wheel, and at least one processor to determine whether the weight on at least one wheel exceeds a weight threshold.

In at least one embodiment, the system further involves at least one wheel sensor to measure a speed of at least one wheel. In some embodiments, to calculate the rate of wheel spin up involves at least one processor using the speed of at least one wheel.

In one or more embodiments, a method for optimizing real-time antiskid control initialization for a vehicle on a travel surface involves determining, with at least one processor, a time T**1** when at least one wheel of the vehicle touches ground. The method further involves determining, with at least one processor, a time T**2** when a speed for at least one wheel is equal to a ground speed. Also, the method involves calculating, with at least one processor, a total time T by subtracting the time T**2** minus the time T**1**. In addition, the method involves determining, with at least one processor, whether the total time T exceeds a time threshold. Additionally, the method involves applying, with at least one brake for at least one wheel, a high level of brake force, when the total time T exceeds the time threshold. Further, the method involves applying, with at least one brake for at least one wheel, a low level of brake force, when the total time T does not exceed the time threshold.

In at least one embodiment, the method further involves measuring, with at least one wheel sensor, the speed for at least one wheel. In some embodiments, the method further involves determining, with at least one processor, the ground speed.

In one or more embodiments, the determining of the time T**1** when at least one wheel of the vehicle touches the ground involves determining, with at least one wheel sensor, a weight on at least one wheel; and determining, with at least one processor, whether the weight on at least one wheel exceeds a weight threshold. In one or more embodiments, the time threshold is around 0.5 seconds (sec).

In at least one embodiment, a system for optimizing real-time antiskid control initialization for a vehicle on a travel surface involves at least one processor to determine a time T**1** when at least one wheel of the vehicle touches ground, to determine a time T**2** when a speed for at least one wheel is equal to a ground speed, to calculate a total time T by subtracting the time T**2** minus the time T**1**, and to determine whether the total time T exceeds a time threshold. The system further involves at least one brake, for at least one wheel, to apply a high level of brake force when the total time T exceeds the time threshold, and to apply a low level of brake force when the total time T does not exceed the time threshold.

In one or more embodiments, the system further involves at least one wheel sensor to measure the speed for at least one wheel. In at least one embodiment, at least one processor is further to determine the ground speed.

In at least one embodiment, to determine the time T**1** when at least one wheel of the vehicle touches the ground involves at least one wheel sensor to determine a weight on at least one wheel, and at least one processor to determine whether the weight on at least one wheel exceeds a weight threshold.

The features, functions, and advantages can be achieved independently in various embodiments of the present inventions or may be combined in yet other embodiments.

DRAWINGS

These and other features, aspects, and advantages of the present disclosure will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. **1** is a schematic representation of a portion of an electric brake system suitable for use in an aircraft (i.e. a vehicle) that may be employed by the disclosed system for optimized antiskid control initialization for dry and wet runways as a function of wheel spinup, in accordance with at least one embodiment of the present invention.

FIG. **2** is a schematic representation of a brake control architecture suitable for use in an electric brake system for an aircraft (i.e. a vehicle) that may be employed by the disclosed system for optimized antiskid control initialization for dry and wet runways as a function of wheel spinup, in accordance with at least one embodiment of the present invention.

FIG. **3** is a graph showing exemplary wheel speed for an aircraft as a function of time for dry runway conditions and for wet/contaminated runway conditions, in accordance with at least one embodiment of the present invention.

FIG. **4** is a graph illustrating exemplary brake clamping force for an aircraft as a function of time for dry runway conditions and for wet/contaminated runway conditions, in accordance with at least one embodiment of the present invention.

FIG. **5** is a flow chart for the disclosed method for optimized antiskid control initialization for dry and wet runways as a function of wheel spinup, that uses the rate of wheel spin up to estimate the runway condition, in accordance with at least one embodiment of the present invention.

FIG. **6** is a flow chart for the disclosed method for optimized antiskid control initialization for dry and wet runways as a function of wheel spinup, that uses the time of wheel spin up to estimate the runway condition, in accordance with at least one embodiment of the present invention.

DESCRIPTION

The methods and apparatus disclosed herein provide an operative system for optimized, real-time antiskid control initialization for travel surfaces in varying conditions, as a function of data for wheel spinup of the vehicle. The disclosed system provides a solution that monitors the wheel speed data of the vehicle, for example, during the touchdown and derotation portion of an aircraft landing (i.e. the lowering of the nosewheel of the aircraft to the runway following the main gear touchdown), and then based on that information, selects the appropriate antiskid control initialization for the condition of the travel surface.

As previously mentioned above, existing vehicle antiskid control initialization is optimized for dry travel surfaces, due to the lack of input to indicate the real-time conditions. Wet and/or contaminated travel surfaces have lower friction coefficients. Failure to adjust for varying surface conditions can result in a delay in the initialization of the antiskid controller, which in turn can result in releasing brake pressure too soon and/or failing to adequately control excessive wheel skid.

The system of the invention allows for the determination of the appropriate antiskid control initialization-based on the real-time condition of a travel surface (e.g., a wet or dry runway) before braking, detected by wheel spinup on the surface, for example during touchdown and de-rotation of an aircraft.

In particular, the system of the invention determines real-time travel surface conditions (e.g., whether the surface is wet or dry) by using wheel speed data. By determining the real-time surface conditions based on the wheel speed data, the system allows for the ability to select for the appropriate antiskid control initialization on a real-time, "as needed" basis. As such, the system is able to determine travel surface conditions (e.g., characteristics of a runway surface) in order to properly initiate antiskid action, and to inform the vehicle's driver or pilot or autopilot, and vehicle controls accordingly. Thus, the disclosed system enhances the safety of landing, improves the antiskid control system performance, and increases the life of the tires of a vehicle, thereby decreasing needed maintenance expense and time.

In the following description, numerous details are set forth in order to provide a more thorough description of the system. It will be apparent, however, to one skilled in the art, that the disclosed system may be practiced without these specific details. In the other instances, well known features have not been described in detail so as not to unnecessarily obscure the system.

Embodiments of the invention may be described herein in terms of functional and/or logical block components and various processing steps. It should be appreciated that such block components may be realized by any number of hardware, software, and/or firmware components configured to perform the specified functions, including "off the shelf" components. For example, an embodiment of the invention may employ various integrated circuit components, e.g., memory elements, digital signal processing elements, logic elements, look-up tables, or the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices. In addition, those skilled in the art will appreciate that embodiments of the present invention may be practiced in conjunction with a variety of different aircraft brake systems and aircraft configurations, and that the system described herein is merely one example embodiment of the invention.

For the sake of brevity, conventional techniques and components related to signal processing, aircraft brake systems, brake system controls, and other functional aspects of the systems (and the individual operating components of the systems) may not be described in detail herein. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent example functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in an embodiment of the invention.

The following description refers to structural elements or nodes or features being "coupled" together. As used herein, unless expressly stated otherwise, "coupled" means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically. Thus, although the schematic representations shown in the figures depict example arrangements of elements, additional intervening elements, devices, features, or components may be present in an embodiment of the invention.

FIG. **1** is a schematic representation of a portion of an electric brake system **100** of the invention suitable for use in an aircraft (not shown). Electric brake system **100** includes a brake pedal **102**, a brake system control unit (BSCU) **104** coupled to brake pedal **102**, an electric brake actuator control (EBAC) **106** coupled to BSCU **104**, and a brake mechanism **108** coupled to EBAC **106**. Brake mechanism **108** corresponds to at least one wheel **110** of the aircraft. Electric brake system **100** may also include an axle-mounted remote data concentrator (RDC) **112** coupled to wheel **110**. Briefly, BSCU **104** reacts to manipulation of brake pedal **102** and generates control signals that are received by EBAC **106**. In turn, EBAC **106** generates brake mechanism control signals that are received by brake mechanism **108**. In turn, brake mechanism **108** actuates to slow the rotation of wheel **110**. These features and components are described in more detail below.

Electric brake system **100** can be applied to any number of electric braking configurations for an aircraft, and electric brake system **100** is depicted in a simplified manner for ease of description. An embodiment of electric brake system **100** may include a left subsystem architecture and a right subsystem architecture, where the terms “left” and “right” refer to the port and starboard of the aircraft, respectively. In practice, the two subsystem architectures may be independently controlled in the manner described below. In this regard, an embodiment of electric brake system **100** as deployed may include a left brake pedal, a right brake pedal, a left BSCU, a right BSCU, any number of left EBACs coupled to and controlled by the left BSCU, any number of right EBACs coupled to and controlled by the right BSCU, a brake mechanism for each wheel (or for each group of wheels), and an RDC for each wheel (or for each group of wheels). In operation, the electric brake system can independently generate and apply brake actuator control signals for each wheel of the aircraft or concurrently for any group of wheels.

Brake pedal **102** is configured to provide pilot input to electric brake system **100**. The pilot physically manipulates brake pedal **102**, resulting in deflection or movement (i.e., some form of physical input) of brake pedal **102**. This physical deflection is measured from its natural position by a hardware servo or an equivalent component, converted into a BSCU pilot command control signal by a transducer or an equivalent component, and sent to BSCU **104**. The BSCU pilot command control signal may convey brake pedal sensor data that may include or indicate the deflection position for brake pedal **102**, the deflection rate for brake pedal **102**, a desired braking condition for brake mechanism **108**, or the like.

An embodiment of electric brake system **100** may use any number of BSCUs **104**. For ease of description, this example includes only one BSCU **104**. BSCU **104** is an electronic control unit that has embedded software that digitally computes EBAC control signals that represent braking commands. The electrical/software implementation allows further optimization and customization of braking performance and brake onset if needed for the given aircraft deployment.

BSCU **104** may be implemented or performed with a general purpose processor, a content addressable memory, a digital signal processor, an application specific integrated circuit, a field programmable gate array, any suitable programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof, designed to perform the functions described herein. A processor may be realized as a microprocessor, a controller, a microcontroller, or a state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a digital signal processor core, or any other such configuration. In one embodiment, the BSCU **104** employs a computer processor (such as a PowerPC 555) that hosts software and provides external interfaces for the software.

BSCU **104** monitors various vehicle inputs to provide control functions such as, without limitation: pedal braking; parking braking; automated braking; and gear retract braking. It should be noted that BSCU **104** is always on. In addition, BSCU **104** blends antiskid commands (which could be generated internally or externally from BSCU **104**) to provide enhanced control of braking. BSCU **104** obtains pilot command control signals from brake pedal **102** (i.e. the pilot controls the brake pedals that the BSCU **104** senses to control the deceleration of the vehicle), along with wheel data (e.g., wheel speed, rotational direction, tire pressure, etc.) from RDC **112**, as described in more detail below. As such, BSCU **104** continually monitors any movement of brake pedal **102** along with the speed of wheel **110**. It should be noted that although relatively independent of BSCU **104**, use of brake pedal **102** is required in order for wheel **110** to skid. In addition, brake pedal **102** has to be applied with a brake pressure greater than the brake pressure required for wheel **110** to skid before antiskid initializes (e.g., before antiskid commands are generated).

Also, BSCU **104** processes its input signals and generates one or more EBAC control signals that are received by EBAC **106**. In practice, BSCU **104** transmits the EBAC control signals to EBAC **106** via a digital data bus. In a generalized architecture (not shown), each BSCU can generate independent output signals for use with any number of EBACs under its control.

BSCU **104** may be coupled to one or more associated EBACs **106**. EBAC **106** may be implemented, performed, or realized in the manner described above for BSCU **104**. In one embodiment, EBAC **106** is realized with a computer processor (such as a PowerPC 555) that hosts software, provides external interfaces for the software, and includes suitable processing logic that is configured to carry out the various EBAC operations described herein. EBAC **106** obtains EBAC control signals from BSCU **104**, processes the EBAC control signals, and generates the brake mechanism control signals (brake actuator signals) for brake mechanism **108**.

Notably, the functionality of BSCU **104** and EBAC **106** may be combined into a single processor-based feature or component. In this regard, BSCU **104**, EBAC **106**, or the combination thereof can be considered to be a brake control architecture for electric brake system **100**. Such a brake control architecture includes suitably configured processing logic, functionality, and features that support the load alleviation and brake control operations described herein.

Wheel **110** may include an associated brake mechanism **108**. EBAC **106** controls brake mechanism **108** to apply, release, modulate, and otherwise control the actuation of one or more components of brake mechanism **108**. In this regard, EBAC **106** generates the brake mechanism control signals in response to the respective EBAC control signals generated by BSCU **104**. The brake mechanism control signals are suitably formatted and arranged for compatibility with the particular brake mechanism **108** utilized by the aircraft. In practice, the brake mechanism control signals may be regulated to carry out anti-skid and other braking maneuvers. Those skilled in the art are familiar with aircraft brake mechanisms and the general manner in which they are controlled, and such known aspects will not be described in detail here.

Electric brake system **100** may include or communicate with one or more sensors **111** for wheel **110**. These sensors **111** are suitably configured to measure wheel data (wheel speed, direction of wheel rotation, tire pressure, wheel/brake temperature, etc.) for wheel **110**, where the wheel data can be utilized by electrical braking system **100**. RDC **112** is generally configured to receive, measure, detect, or otherwise obtain data for processing and/or transmission to another component of electric brake system **100**. Here, RDC **112** is coupled to (or is otherwise associated with) wheel **110**, and RDC **112** is configured to collect and transmit its wheel data to BSCU **104**. The digital data communication bus or buses on the aircraft may be configured to communicate the wheel data from RDC **112** to BSCU **104** using any suitable data communication protocol and any suitable data transmission scheme. In an alternate embodiment, RDC **112** may be configured to communicate the wheel data to EBAC **106**. In yet another embodiment, RDC **112** may be configured to communicate the wheel data to BSCU **104** and EBAC **106**.

In this example, electric brake system **100** is suitably configured to control the actuation of brake mechanism **108** in response to the wheel data. In particular, electric brake system **100** is configured to control the actuation of brake mechanism **108** in response to a wheel speed value, which indicates the current speed of the aircraft.

Electric brake system **100** can be utilized to alleviate dynamic structural loads (e.g., landing gear loads) during high effort braking of the aircraft. Electric brake system **100** generally commands brake mechanism **108** to generate brake torque in a manner that is related to the amount that brake pedal **102** is deflected by the pilot. This control can take into account the deflection position of brake pedal **102**, the deflection rate of brake pedal **102**, and/or the speed at which the aircraft is traveling to modify the actuation of brake mechanism **108** such that the desired brake torque is obtained at a suitable rate that does not develop high peak dynamic loads. This allows the aircraft landing gear to be designed with less weight and bulk, which benefits aircraft performance. In one embodiment, electric brake system **100** uses sensors **103** at brake pedal **102** to measure the deflection and deflection rate of brake pedal **102**. BSCU **104** processes these inputs to reduce the initial onset rate of brake application, which in turn reduces the peak brake load that has to be absorbed by the landing gear structure. The brake control laws can be tuned for the particular model of aircraft, static, dynamic, or operational characteristics of the aircraft, and/or static, dynamic, or operational characteristics of brake mechanism **108**.

FIG. **2** is a schematic representation of a brake control architecture **200** suitable for use in an electric brake system for an aircraft. Electric brake system **100** may employ an embodiment of brake control architecture **200**. For example, brake control architecture **200** may be implemented or realized in BSCU **104** and/or EBAC **106**. Brake control architecture **200** may include, without limitation: a processor **202** having suitably configured processing logic; an appropriate amount of memory **204**; and a brake mechanism control signal generator **206**. Brake control architecture **200** may, but need not, include a brake application profile generator **208**. These elements may be coupled together using a data communication bus **209** or any suitably configured interconnection architecture or arrangement. In this embodiment, brake control architecture **200** is configured to obtain and process brake pedal sensor data **210** and wheel speed data **212** in the manner described in more detail below.

Processor **202** may be implemented, performed, or realized in the manner described above for BSCU **104**. The processing logic corresponding to processor **202** is designed to carry out various operations and functions associated with the electric brake control scheme described herein. Furthermore, a method or algorithm (or portions thereof) described in connection with the embodiments disclosed herein may be embodied directly in hardware, in firmware, in a software module executed by processor **202**, or in any practical combination thereof. A software module may reside in memory **204**, which may be realized as one or more physical components having RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. In this regard, memory **204** can be coupled to processor **202** such that processor **202** can read information from, and write information to, memory **204**. In the alternative, memory **204** may be integral to processor **202**. As an example, processor **202** and memory **204** may reside in an ASIC.

Memory **204** may be configured to store at least one brake application profile **214** for the aircraft. Brake application profile **214** influences the manner in which the brake mechanism is actuated. Brake application profile **214** may be predetermined and programmed into brake control architecture **200** or generated in real-time by brake application profile generator **208**. In the former situation, brake application profile **214** may be based upon static, dynamic, aerodynamic, operational, and/or other characteristics of the aircraft (e.g., the mass of the aircraft and the typical landing speed of the aircraft) and/or based upon static, dynamic, operational and/or other characteristics of the electric brake system or brake mechanism (e.g., the response time of the control elements, the maximum achievable brake torque, and the typical range of brake torque). In the latter situation, the optional brake application profile generator **208** may be utilized to generate brake application profile **214** dynamically in response to brake pedal sensor data **210** and/or in response to wheel speed data **212**. The operation of brake application profile generator **208** may also be influenced by aircraft characteristics and/or brake mechanism characteristics as mentioned above. In practice, brake application profile generator **208** may be realized in the processing logic of processor **202**.

FIG. **3** is a graph **300** showing exemplary wheel speed for an aircraft as a function of time for dry runway conditions **310** and for wet/contaminated runway conditions **320**, in accordance with at least one embodiment of the present disclosure. In this figure, the y-axis denotes wheel speed, and the x-axis denotes time. In particular, the graph **300** shows the wheel speed as a function of time for dry runway conditions **310** and for wet/contaminated runway conditions **320** starting from the time T**1** the aircraft touches down onto the runway with an initial wheel speed of Y**1** (i.e. zero) to the time T**2** when reaching the aircraft ground speed Y**2** without slippage.

FIG. **4** is a graph **400** illustrating exemplary brake clamping force for an aircraft as a function of time for dry runway conditions **410** and for wet/contaminated runway conditions **420**, in accordance with at least one embodiment of the present invention. In this figure, the y-axis denotes brake clamping force, and the x-axis denotes time. Specifically, the graph **400** shows the brake clamping force as a function of time for dry runway conditions **410** and for wet/contaminated runway conditions **420** starting from the time T**1** the aircraft touches down onto the runway. The brake clamping force antiskid is initialized to a lower level F**1** for wet/contaminated runway conditions. Conversely, the brake clamping force antiskid is initialized to a higher level F**2** for dry runway conditions.

FIG. **5** is a flow chart for the disclosed method **500** for optimized antiskid control initialization for dry and wet travel surfaces as a function of wheel spinup, that uses the rate of wheel spin up to estimate the surface condition, in accordance with at least one embodiment of the present invention. At the start **510** of the method **500**, at least one processor determines when at least one wheel of the vehicle (e.g., an aircraft) touches the ground by determining, with at least one wheel sensor, the weight on at least one wheel and by determining, with at least one processor, whether the weight on at least one wheel exceeds a weight threshold **520**. In one or more embodiments, the weight threshold is related to the size of the vehicle.

If the processor determines that the weight on at least one wheel does not exceed the weight threshold, the method **500** returns to the start **510**. However, if the processor determines that the weight on at least one wheel does exceed the weight threshold, the method **500** proceeds to step **530**.

Then, at step **530**, at least one wheel sensor measures the speed of at least one wheel (e.g., in feet per seconds (ft/sec)) **530**. At least one processor then calculates a rate of wheel spin up for at least one wheel (e.g., in feet per seconds squared (ft/sec^2)) by using the measured speed of at least one wheel **540**.

At least one processor then determines whether the calculated rate of wheel spin up exceeds a wheel spin up rate threshold **550**. In one or more embodiments, the wheel spin up rate threshold is around 1000 ft/sec^2. If it is determined that the rate of wheel spin up does not exceed the wheel spin up rate threshold, it is assumed that the runway is wet and at least one brake will apply a low level of brake force for at least one wheel **560**. In one or more embodiments, the low level of brake force is about 300 to 1500 pounds per square inch (psi). It should be noted that these are typical values for brake pressure reduced by the antiskid system, if it is determined that the runway is wet. In other embodiments, various different values for the low level of brake force may be utilized.

However, if it is determined that the rate of wheel spin up does exceed the wheel spin up rate threshold, it is assumed that the runway is dry and at least one brake will apply a high level of brake force for at least one wheel **570**. In one or more embodiments, the high level of brake force is about 1500 to 3000 psi. It should be noted that these are typical values for brake pressure applied by the antiskid system, if it is determined that the runway is dry. In other embodiments, various different values for the high level of brake force may be used. Also, it should be noted that in one or more embodiments, at least one brake is a forward brake and/or an aft brake. Then, the method **500** ends **580**.

FIG. **6** is a flow chart for the disclosed method **600** for optimized antiskid control initialization for dry and wet runways as a function of wheel spinup, that uses the time of wheel spin up to estimate the runway condition, in accordance with at least one embodiment of the present disclosure. At the start **605** of the method **600**, at least one processor determines when at least one wheel of the vehicle (e.g., an aircraft) touches the ground **615** by determining, with at least one wheel sensor, the weight on at least one wheel and by determining, with at least one processor, whether the weight on at least one wheel exceeds a weight threshold **610**. In some embodiments, the weight threshold is related to the size of the vehicle.

If the processor determines that the weight on at least one wheel does not exceed the weight threshold, the method **600** returns to the start **605**. However, if the processor determines that the weight on at least one wheel does exceed the weight threshold, the method **600** proceeds to step **615**.

At step **615**, the processor determines the time T**1** when at least one wheel of the vehicle touches the ground, which is indicated by the weight threshold being exceeded. Then, at least one wheel sensor measures the speed of at least one wheel (e.g., ft/sec) **620**. At least one processor then determines the ground speed (e.g., ft/sec). **625**. Then, at least one processor determines wheel slippage (e.g., ft/sec) by calculating the wheel speed minus the ground speed **630**.

At least one processor then determines if the wheel slippage is equal to zero **635**. If it is determined that the wheel slippage is not equal to zero, this indicates that the wheel speed is not equal to the ground speed, and the method **600** returns to step **630**. However, if it is determined that the wheel slippage is equal to zero, this indicates that the wheel speed is equal to the ground speed, and the method **600** proceeds to step **640**.

At step **640**, at least one processor determines the time T**2** when the wheel speed is equal to the ground speed **640**. Then, at least one processor determines a total time T by calculating the time T**2** minus the time T**1** **645**.

At least one processor then determines whether the calculated total time T exceeds a time threshold **650**. In one or more embodiments, the time threshold is around 0.5 seconds (sec). If it is determined that the total time T does not exceed the time threshold, it is assumed that the runway is wet and at least one brake will apply a low level of brake force for at least one wheel **655**. In at least one embodiment, the low level of brake force is about 300 to 1500 pounds per square inch (psi). However, if it is determined that the total time T does exceed the time threshold, it is assumed that the travel surface is dry and at least one brake will apply a high level of brake force for at least one wheel **660**. In some embodiments, the high level of brake force is about 1500 to 3000 psi. Then, the method **600** ends **665**.

It should be noted that the vehicle employed by the disclosed system, method, and apparatus for optimized antiskid control initialization for travel surfaces in variable conditions as a function of wheel spinup may be an airborne vehicle. In some embodiments, the airborne vehicle may be an aircraft or a space plane. For these embodiments, the forward and aft brakes are associated with at least one landing gear truck containing at least one wheel. It should also be noted that in some embodiments, a vehicle speed sensor(s) (e.g., a sensor (s) that measures linear velocity) may be used instead or in conjunction with a wheel speed sensor(s) (e.g., a sensor(s) that measures rotational velocity). For these embodiments, a vehicle speed threshold value may be utilized as well.

Although particular embodiments have been shown and described, it should be understood that the above discussion is not intended to limit the scope of these embodiments. While embodiments and variations of the many aspects of the invention have been disclosed and described herein, such disclosure is provided for purposes of explanation and illustration only. Thus, various changes and modifications may be made without departing from the scope of the claims.

Where methods described above indicate certain events occurring in certain order, those of ordinary skill in the art having the benefit of this disclosure would recognize that the ordering may be modified and that such modifications are in accordance with the variations of the invention. Additionally, parts of methods may be performed concurrently in a parallel process when possible, as well as performed sequentially. In addition, more parts or less part of the methods may be performed.

Accordingly, embodiments are intended to exemplify alternatives, modifications, and equivalents that may fall within the scope of the claims.

Although certain illustrative embodiments and methods have been disclosed herein, it can be apparent from the foregoing disclosure to those skilled in the art that variations and modifications of such embodiments and methods can be made without departing from the true spirit and scope of the art disclosed. Many other examples of the art disclosed exist, each differing from others in matters of detail only. Accordingly, it is intended that the art disclosed shall be limited only to the extent required by the appended claims and the rules and principles of applicable law.

I claim:

1. A method for optimizing real-time antiskid control initialization for a vehicle on a travel surface, the method comprising:

determining, with at least one processor, a time when at least one wheel of the vehicle touches ground;

calculating, with the at least one processor, a rate of wheel spin up for the at least one wheel;

determining, with the at least one processor, whether the rate of wheel spin up exceeds a wheel spin up rate threshold;

applying, with at least one brake for the at least one wheel, a high level of brake force, when the rate of wheel spin up exceeds the wheel spin up rate threshold; and

applying, with the at least one brake for the at least one wheel, a low level of brake force, when the rate of wheel spin up does not exceed the wheel spin up rate threshold.

2. The method of claim **1**, wherein the determining of the time when the at least one wheel of the vehicle touches the ground comprises:

determining, with at least one wheel sensor, a weight on the at least one wheel; and

determining, with the at least one processor, whether the weight on the at least one wheel exceeds a weight threshold.

3. The method of claim **2**, wherein the weight threshold is related to a size of the vehicle.

4. The method of claim **1**, wherein the method further comprises measuring, with at least one wheel sensor, a speed of the at least one wheel.

5. The method of claim **4**, wherein the calculating of the rate of wheel spin up comprises the at least one processor using the speed of the at least one wheel.

6. The method of claim **1**, wherein the wheel spin up rate threshold is around 1000 feet per second squared (ft/sec^2).

7. The method of claim **1**, wherein the high level of brake force is about 1500 to 3000 pounds per square inch (psi).

8. The method of claim **1**, wherein the low level of brake force is about 300 to 1500 psi.

9. The method of claim **1**, wherein the vehicle is one of an aircraft and a space plane.

10. The method of claim **1**, wherein the at least one brake is at least one of a forward brake and an aft brake.

11. A system for optimized antiskid control initialization for a vehicle, the system comprising:

at least one processor to determine a time when at least one wheel of the vehicle touches ground, to calculate a rate of wheel spin up for the at least one wheel, and to determine whether the rate of wheel spin up exceeds a wheel spin up rate threshold; and

at least one brake, for the at least one wheel, to apply a high level of brake force when the rate of wheel spin up exceeds the wheel spin up rate threshold, and to apply a low level of brake force when the rate of wheel spin up does not exceed the wheel spin up rate threshold.

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